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Biotic indicators of carabid species richness on organically and conventionally managed arable fields

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Abstract

Carabids, a species rich arthropod family, potentially contribute much to biodiversity in agroecosystems, but assessing and monitoring carabid diversity is costly and time consuming. Therefore, this study aimed at finding more easily measurable parameters indicating high carabid diversity within organic and conventional management systems. Cover and number of weed species as well as activity density of single carabid species and of total carabids were investigated as potential indicators of carabid species richness. The study was carried out near Reckenfeld in Westphalia on sandy Plaggenesch soils. Three organically and four conventionally managed fields (cereals and corn) were investigated at the field margins and in the field centres from April to August 1999. Additionally, data of carabid catches and weed flora in winter cereals from an extended study in Düren (Northrhine-Westphalia) were reanalysed to validate the results. However, neither of the potential indicators showed consistently significant positive correlation with carabid diversity. This is partly attributed to the low variability of management conditions within the management systems in the studies presented.

Keywords: Carabidae; Biodiversity correlates; Bioindicators; Organic agriculture

1. Introduction

In many studies diversity of both flora and arthropod fauna has found to be higher on organically compared to conventionally managed fields (e.g., Frieben, 1997; Pfiffner, 1997). However, as biodiversity varies within each of the management systems, organic farming is not appropriate as an exclusive indicator of high biodiversity. Therefore, additional indicators are needed.

In the context of biodiversity, the term “indicator” is often used with very different definitions. These can be classified into at least four categories: (a) biotic indicators of abiotic conditions (Platen, 1995; Stumpf, 1997); (b) biotic indicators of human practices, including, e.g., pollution sensitive species (Basedow, 1990); (c) goal parameters, which are deducted from normatively set nature conservation aims and translate these into measurable features, e.g., species diversity of a certain taxon (May, 1995); (d) correlates of goal parameters, which make it possible to reduce labour and costs in assessing biodiversity and at the same time minimise loss of information. These correlates can be taxa, biotic parameters like species richness (Duelli and Obrist, 1998), or human practices influencing biodiversity (van Elsen, 1996). In this study based on data of flora and carabid fauna on arable fields in

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Northrhine-Westphalia, the focus is on the category of correlates.

Carabids, a species rich arthropod family, potentially contribute much to biodiversity in agroecosystems, but assessing and monitoring carabid diversity is costly and time consuming. Therefore, this study aimed at finding more easily measurable biotic parameters indicating high carabid diversity.

2. Material and methods

2.1. Study area and field methods

The study area is located near Reckenfeld at 40–48 m above sea level, 15 km north of Münster in the region "Westfälische Bucht", with a maritime climate (average annual air temperature of 9.1 °C, annual precipitation 750 mm). Soils are mainly sandy, dominating soil types are anthrosols with plaggic horizons rich in organic matter (Plaggenesch), and gleyic podzols. Three organically and four conventionally managed arable fields were investigated (for management data see Table 1). Carabids were sampled from 19 April to 9 August 1999 with pitfall traps of 10 cm diameter (Melber, 1987). Renner's solution was used as a preservative (40% ethanol, 30% water, 20% glycerine, 10% acetic acid; Renner, 1982). Three traps were placed at the margin and in the centre of each of the seven fields (total of 42 traps). All individuals captured were identified up to species level. Vegetation was investigated according to Braun–Blanquet (Wilmanns, 1993, p. 50). Ground cover of weed vegetation was estimated visually.

Additionally, data from an extended study in Düren/Northrhine-Westphalia published by König et al. (1989) were reanalysed (30 winter cereal plots from 4 years; Winkens, 1984–1986; Wolff-Straub, 1989).

2.2. Choice of goal parameter and potential indicators

Carabid species were classified into five habitat preference groups using Thiele (1977), Koch (1989), Turin et al. (1991) and Marggi (1992): (1) stenotopic woodland species; (2) eurytopic woodland species; (3) eurytopic species; (4) eurytopic field species and (5) stenotopic field species. Species number of field species (eurytopic and stenotopic) was chosen as goal parameter for two reasons. First, field species are more typical for arable fields than woodland or eurytopic species and the promotion or protection of woodland species on arable fields is not possible. Second, edge effects could be minimised by the exclusion of woodland species from the calculations.

Four parameters were chosen as potential indicators of carabid species richness: (1) activity density of all carabids; (2) activity density of single carabid species; (3) number of plant species; (4) percentage ground cover of weed species.

2.3. Data analysis

The number of carabid individuals were $\log_{10}(x + 1)$-transformed before further statistical calculations. Statistical analysis of both studies comprised the calculation of Pearson's correlation coefficient and linear

Table 1
Management data of studied fields in Reckenfeld/Northrhine-Westphalia 1999

	Management						
	Organic			Conventional			
Crop in 1999	Faba–beans–oats	Triticale	Corn	Triticale	Winter wheat	Corn	Corn
Crop in 1998	Winter wheat	Corn	Ley	Corn	Corn	Winter barley	Corn
N-fertilisation (kg N/ha)	0	200	140	110	225	180	100
Frequency of mechanical weed control	3	2	5	0	0	0	0
Pesticides and growth regulator	–	–	–	Herbicide, growth regulator	Herbicides, insecticides, fungicides, growth regulators	Herbicides	Herbicides

regression between the goal parameter mentioned above and potential indicator parameters (Sachs, 1999; also see Sokal and Rohlf, 1995, pp. 543, 556–558). High positive correlation of a potential indicator with a goal parameter is seen as a measure of indicator reliability. However, causal relationships cannot be deducted from these calculations.

In most cases the factor "management system" (conventional vs. organic) which contributes much to the variation of diversity is already known or information is easily available. Therefore, no biotic indicators are needed to indicate the management system, but indicators are useful that predict the rest of variability of diversity within the management system. Accordingly, correlation between potential indicators and the goal parameter was calculated separately for organic and conventional fields.

3. Results

Total carabid catch was correlated significantly with the number of field species in the Düren study, but not in the Reckenfeld study (Fig. 1, Table 2). In the organic fields this correlation was higher than in the conventional ones in both studies.

Correlation between the number of individuals of single carabid species and the number of field species did not give a consistent picture for any of the species. For none of them there was significant correlation throughout both studies and both management systems (Table 3); however, the number of *Asaphidion flavipes* correlated significantly with the number of field species in the organic fields both from the Reckenfeld and the Düren study. *Pterostichus melanarius* and *Trechus quadristriatus* showed negative correlation values for the conventional fields from Reckenfeld.

The number of carabid field species correlated positively and significantly with the number of plant species only in the organic fields from Reckenfeld (Fig. 2, Table 2). For both the organic and the conventional management system the data from Düren correlation was negative, but not significant for the conventional sites.

Total cover estimates of weed vegetation could not be used to predict species numbers of carabids (data not presented). Single weed species cover estimates, especially of *Vicia hirsuta*, *Matricaria recutita* and *Stellaria media*, showed moderate correlation with species richness of field carabids (Table 4). These plant species are typical of the site specific weed community.

4. Discussion

As the total carabid catch was correlated with the goal parameter "number of carabid field species" only in the Düren study, it is not likely to be a reliable indicator of carabid diversity. Although correlation between the number of carabid species and the number

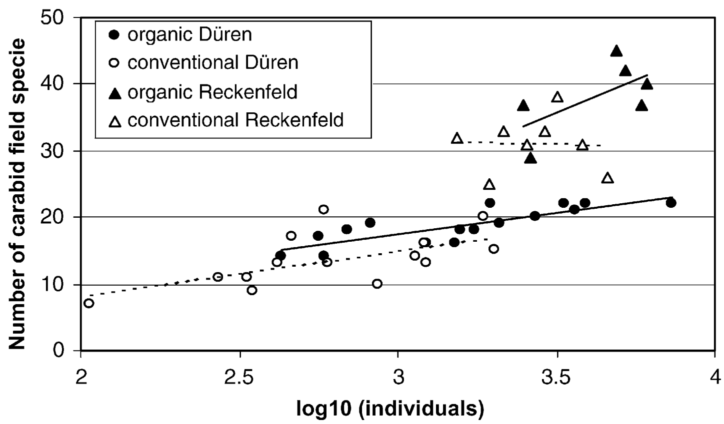

Fig. 1. Individuals of carabids ($\log(x + 1)$) caught in 44 arable fields plotted against number of carabid field species. Solid lines: organic; broken lines: conventional. For statistics see Table 2.

Table 2
Species number of carabid field species (y) as a function of two potential indicators

Indicator (x)	Site	Management	d.f.[a]	R^2	Regression equation
log (total individuals)	Reckenfeld	Organic	4	0.41, ns[b]	$y = 20.0x - 34.4$
		Conventional	6	0.00, ns	$y = -1.09x + 34.9$
	Düren	Organic	13	0.70***	$y = 6.38x - 1.7$
		Conventional	13	0.39*	$y = 6.89x - 5.7$
Plant species number	Reckenfeld	Organic	4	0.92**	$y = 0.63x + 20.7$
		Conventional	6	0.33, ns	$y = 0.30x + 27.9$
	Düren	Organic	11	0.31*	$y = -0.40x + 25.0$
		Conventional	5	0.10, ns	$y = -0.34x + 16.7$

[a] Degrees of freedom: Düren d.f. = 13, Reckenfeld organic d.f. = 4, conventional d.f. = 6.
[b] Not significant.
* Significant at $P \leq 0.05$.
** Significant at $P \leq 0.01$.
*** Significant at $P \leq 0.001$.

of individuals may be significant in other studies (e.g., Luff, 1996), residual variation remains too high for prediction purposes.

From a practical point of view it is easier to monitor only one or two carabid species than full determination of all carabid individuals. However, none of the carabid species caught in the studies from Reckenfeld and Düren can be regarded as a reliable indicator of high carabid diversity. Moreover, there is probably no (direct) causal connection between carabid species richness and the abundance of a single carabid species. Because of these restrictions, a different

Table 3
Carabid species as indicators of carabid diversity[a]

Carabid species	Reckenfeld		Düren	
	Organic	Conventional	Organic	Conventional
Agonum muelleri (Herbst 1758)	0.87*	0.23, ns[b]	0.35, ns	0.23, ns
Amara aenea (DeGeer 1774)	0.38, ns	0.72*	0.54*	0.48, ns
Amara similata (Gyll. 1810)	0.91*	0.69, ns	0.35, ns	0.70**
A. flavipes (L. 1761)	0.90*	0.11, ns	0.81***	0.36, ns
Bembidion lampros (Herbst 1784)	0.36, ns	−0.18, ns	0.56*	0.24, ns
Bembidion tetracolum Say 1823	0.47, ns	0.39, ns	0.68**	0.49, ns
Calathus fuscipes (Goeze 1777)	0.14, ns	−0.12, ns	0.53*	0.11, ns
Harpalus affinis (Schrank 1781)	0.31, ns	0.44, ns	0.25, ns	0.80***
Loricera pilicornis (F. 1775)	0.21, ns	0.24, ns	0.82***	0.69**
Nebria brevicollis (F. 1792)	−0.44, ns	0.49, ns	0.53*	0.13, ns
Poecilus cupreus (L. 1758)	0.52, ns	−0.01, ns	0.76***	0.64*
Pseudoophonus rufipes (DeGeer 1775)	−0.86, ns	0.13, ns	0.47, ns	0.68**
P. melanarius (Ill. 1789)	0.19, ns	−0.63, ns	0.56*	0.53*
Pterostichus vernalis (Panzer 1796)	−0.02, ns	0.50, ns	0.61*	0.63*
T. quadristriatus (Schrank 1781)	0.10, ns	−0.70, ns	0.63*	0.40, ns

[a] Degrees of freedom: Düren d.f. = 13, Reckenfeld organic d.f. = 4, conventional d.f. = 6. Correlation between captured individuals of carabid species ($\log_{10}(x + 1)$) and number of carabid field species. Species with correlation at least once significant.
[b] Not significant.
* Significant at $P \leq 0.05$.
** Significant at $P \leq 0.01$.
*** Significant at $P \leq 0.001$.

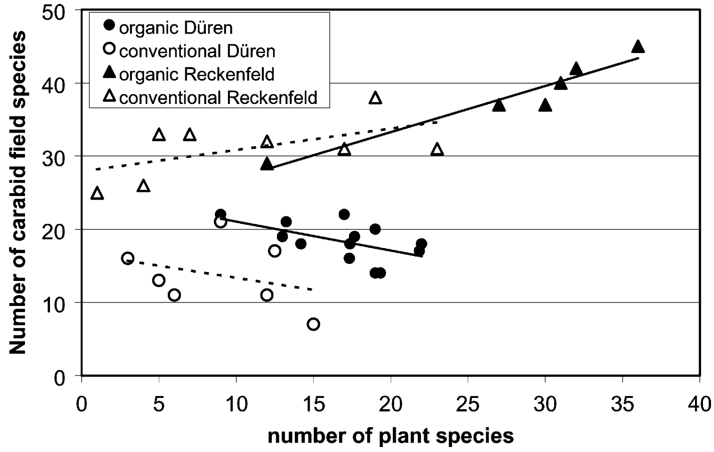

Fig. 2. Number of plant species in 44 arable fields plotted against number of carabid field species. Solid lines: organic; broken lines: conventional. For statistics see Table 2.

approach should be pursued. Ecological classification of carabid species may lead to the specification of conditions that are favourable for high species richness of carabids (Döring and Kromp, this issue).

The connection between high insect diversity and plant species richness is well known for many taxa (e.g., Weiss and Nentwig, 1992; Zanger et al., 1994; Denys, 1997). Carabid species may directly or indirectly profit from species rich vegetation. For example, the species rich subfamilies Harpalinae and Zabrinae contain many herbivorous and omnivorous species (Wachmann et al., 1995). At the same time, species numbers of both vegetation and carabids may be influenced in the same direction by practices in the agricultural management system (e.g., soil tillage; cf. Lorenz, 1994; van Elsen, 1996).

However, number of plant species number was not linked consistently to the number of carabid field species in the studies presented. Correlation was higher in the data from Reckenfeld than in the Düren study. A possible reason for this may be that the data extracted from the Düren study only comprised winter cereal plots, whereas the Reckenfeld data was based on corn as well as cereal fields, thus displaying a higher variability of management conditions. Low correlations between total weed cover estimates and number of carabid species may have resulted from the fact that higher weed cover is able to reduce activity abundance of epigaeic arthropods by reducing movement in general (Heydemann, 1956).

Table 4
Arable plant species as indicators of carabid diversity[a]

Species	Organic	Conventional	Presence
Apera spica-venti	0.60, ns[b]	0.30, ns	11
Capsella bursa-pastoris	0.53, ns	0.67, ns	7
Chenopodium album	0.00, ns	0.32, ns	10
Lamium amplexicaule	0.66, ns	–	5
Lamium purpureum	0.64, ns	–	5
M. recutita	0.71, ns	0.56, ns	9
Myosotis arvensis	0.75, ns	–, ns	5
Polygonum convolvulus	–	0.65, ns	
Polygonum lapathifolium	−0.16, ns	−0.01, ns	5
Polygonum persicaria	−0.25, ns	0.32, ns	7
S. media	0.74, ns	0.51, ns	9
Veronica arvensis	0.27, ns	0.50, ns	5
V. hirsuta	0.69, ns	0.72*	7
Viola arvensis	0.78, ns	−0.41, ns	9

[a] Degrees of freedom: organic d.f. = 4, conventional d.f. = 6. Pearson's correlation coefficient between cover estimates (%) and number of carabid field species. Plant species with presence > 4 out of 14; data from Reckenfeld.

[b] Not significant.

* Significant at $P \leq 0.05$.

5. Conclusions

If any biotic indicators for carabid diversity are to be used, they are presumably only applicable to

comparisons of sites with fairly contrasting management conditions. Within more homogeneous groups of sites, such as organic winter cereal plots, there seem to be no reliable biotic indicators that are more easily measured than carabid species richness itself. For a rough biodiversity assessment of large areas or many sites, though, vegetation may presumably be sufficient (Duelli and Obrist, 1998).

Importantly, with a continuously changing agriculture, the predictive power of any indicator cannot be expected to remain unchanged; with the support of organic agriculture it may be hoped to slow down the loss of sensitive indicator taxa.

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